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EMPIRICAL STUDY

Language Use in Real-Time Interactions During Early Elementary Science Lessons: The Bidirectional Dynamics of the Language Complexity of Teachers and Students

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and Paul van Geert

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This study used a dynamic approach to explore bidirectional sequential relations between the real-time language use of teachers and students in naturalistic early elementary science lessons. It also compared experienced teachers ($n = 22$) with novice teachers ($n = 8$) with respect to such relations. Verbal interactions were transcribed and coded at the utterance level for syntactic complexity, lexical density of content word use, and open-ended teacher questions. Sequential analyses provided evidence for the existence of a bidirectional relationship, meaning that both teachers and students were sensitive to each other's use of complex and dense language. In addition, the use of open-ended teacher questions was related to complex and dense student utterances. Comparisons between experienced teachers and novice teachers revealed that sequential patterns were stronger in the case of experienced teachers, suggesting that there were more flexible adaptation processes in this group.

Keywords language; real-time interaction; bidirectional relation; sequential analysis; early elementary science education

Introduction

Language is learned most effectively in meaningful contexts, such as content lessons. For this reason, science lessons are suited to provide rich language

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learning opportunities, as language is essential to learning science (Snow, 2014; Wellington & Osborne, 2001). Engagement in these lessons, particularly in early elementary classrooms,¹ both demands and supports sophisticated science discourse. Science discourse differs from the informal everyday language of students in that it is accompanied by sophisticated forms of language use, such as domain-specific vocabulary, dense presentation of information, and complex sentence structures (Halliday, 1993; Schlepppegrell, 2001, 2004). In order to successfully participate in science lessons, students are expected to advance in language; at the same time, science lessons offer opportunities for students to acquire and practice sophisticated language skills. The acquisition of sophisticated forms of language is considered a great challenge because children need to express complex thoughts with limited language skills (Snow & Uccelli, 2009). Large differences in language proficiency when entering school exist between children from different homes (Scheele, Leseman, Mayo, & Elbers, 2012). Therefore, it is important to introduce children to this register from a young age onwards (Schlepppegrell, 2004; Snow, 2010; Snow & Uccelli, 2009).

In the Netherlands, there has been an initiative to promote science learning in elementary school classrooms, as science is not yet part of the standard early elementary school curriculum. This initiative, called *Curious Minds*, is financed by the Dutch Ministry of Education. The program contributes to both scientific understanding of how young children learn science as well as professionalization for teachers who are learning how to teach science in elementary school. Similar programs in, for instance, the United States and Germany have made concentrated attempts to introduce science in early elementary classrooms (French, 2004; Klein, Hammrich, Bloom, & Ragins, 2000; Kramer & Rabe-Kleberg, 2011; National Research Council, 2013; Neumann, Fischer, & Kauertz, 2010). The current study is based on the data from a project within the *Curious Minds* program called “Language as a Tool for Learning Science,” which was designed to implement a professionalization intervention for teachers focused on integrating science and language learning. However, before such an intervention could be designed, implemented, and evaluated, specific characteristics of the verbal interaction processes occurring in naturalistic science classrooms needed to be described. Because verbal interaction is bidirectional in nature, the aim of this study was to investigate bidirectional relations involving the complexity of language use in teacher–student interaction. Insight into these dynamics is important because, ultimately, the intended intervention is aimed at changing (optimizing) the patterns of interaction between teachers and students.

Integration of Science and Language Learning

Science lessons in early elementary school provide opportunities to integrate content learning and language learning (Conezio & French, 2002; French, 2004; French & Peterson, 2009; Glass & Oliveira, 2014; Patrick, Mantzicopoulos, Samarapungavan, & French, 2008), and teachers are not always aware of such opportunities (Wong Fillmore & Snow, 2002). Snow (2014) emphasizes that interesting content facilitates language learning. Existing literature points toward several specific characteristics of teacher talk (e.g., language modeling and evoking strategies) that contribute to the development of sophisticated language skills in students. These characteristics include (a) syntactic complexity, (b) varied vocabulary, and (c) extended discourse and cognitive and linguistic stimulation (Dickinson, 2001; Snow, 2014). Although these qualities of teacher talk describe classroom discourse in general, they are important for learning the language of science and can be seen as elements of what Snow (2014, p. 28) referred to as “talking about interesting things in interesting ways.”

The first characteristic of teacher talk predictive of students’ linguistic development is syntactic complexity of the teacher’s speech. For example, research by Huttenlocher, Vasilyeva, Cymerman, and Levine (2002) revealed that 4-year-old children’s syntactic growth over 1 year was larger in classes where the teacher used more syntactically complex language, compared to when less syntactically complex language was used, although there were substantial individual differences in children’s mastery of complex sentences (4–35% of complex sentences used). Both experimental research and studies in naturalistic settings have also pointed toward effects of exposure to certain syntactic forms in adult input on the use of those forms by children between the ages of 4 and 5 (Huttenlocher, Vasilyeva, & Shimpi, 2004; Vasilyeva, Huttenlocher, & Waterfall, 2006). In addition, other studies have revealed a dynamic and coordinative process in early syntactic development, whereby adults are sensitive to children’s utterances, and children are sensitive to contingent utterances provided by adults (Branigan, Pickering, & Cleland, 2000; Dale & Spivey, 2006).

The second characteristic of teacher talk predictive of students’ linguistic development is varied vocabulary. Several studies have emphasized the importance of lexically dense, diverse, and sophisticated vocabulary in science lessons. By qualitatively examining teacher–student interactions, Peterson and French (2008) found that explanations of specific scientific mechanisms (e.g., gravity or static electricity) were dynamically co-constructed. Over time, students produced more on-topic responses, more content- and task-related terms, and more causal connectives in their responses. Dickinson and Tabors (2001) also claim that exposure to varied vocabulary is beneficial for children’s

vocabulary growth in kindergarten. From a theoretical perspective, lexical density can be viewed as a measure of language complexity (Halliday & Martin, 1993; Schlepppegrell, 2004). So, on the one hand, teachers should employ dense and varied vocabulary in science lessons; on the other hand, adults have the tendency to adapt their language use to the level of the child (Snow, 1972), through the use of limited vocabulary, for instance. Teachers often simplify their language when they consider the information transfer too high for their students (Kallery & Psillos, 2001). Therefore, teachers must be highly sensitive in order to find the right balance between introducing the dense science- and content-related vocabulary that is required in science lessons and adapting to their students' verbal expressions.

With respect to the third characteristic of teacher talk predictive of students' linguistic development, many studies have provided empirical evidence in support of Snow's (2014) message that fostering extended discourse in content lessons is important. For instance, open-ended questioning strategies are found to be the most effective when it comes to stimulating children to talk (Oliveira, 2010). Teachers who used more open-ended questions had students who showed better language development (de Rivera, Giralometto, Greenberg, & Weitzman, 2005; Dickinson, 2001; Mashburn et al., 2008; Peisner-Feinberg et al., 2001). Open-ended questions are less constrained and typically generate longer responses (de Rivera et al., 2005; Wasik & Bond, 2001; Wasik, Bond, & Hindman, 2006); they also provide opportunities for more linguistically and cognitively challenging discourse (Massey, Pence, Justice, & Bowles, 2008). From studies on shared book reading, we know that children adapt the complexity of their language use to match the linguistic demands of the teacher's questions (Danis, Bernard, & Leproux, 2000; Zucker, Justice, Piasta, & Kadaverek, 2010). In early education in general, roughly one third of the teacher's utterances are questions (de Rivera et al., 2005). In science lessons for 4- and 5-year-old children, Lee and Kinzie (2012) found that only 18% of the teacher utterances were devoted to questions, of which 35% were open-ended questions. These open-ended questions elicited complex student responses and responses that employed varied vocabulary. Questions are not only a way to control a conversation (Dickinson, 2001); if matched with the abilities and demands of students, questions can also be used to help children gain understanding through language. This puts high demands on teachers' flexibility and skills to adapt to the needs of their students throughout the science lesson.

In sum, previous research has revealed the effects of several characteristics of teacher talk, including complex sentences, varied vocabulary, and extended discourse, on the language use of students. But how do these predictors of

students' language manifest themselves in the form of real-time interactions during natural science lessons? The current study aimed to answer this question by employing the methodology of sequential analysis.

Bidirectional Properties of Language in Interaction

Existing knowledge about language use in early elementary classrooms is largely based on studies that investigate global associations between the language use of teachers and language outcomes of children (Dickinson & Smith, 1994; Girolametto, Weitzman, & Greenberg, 2003; Snow, 1983). However, language use is a process that takes place at the level of the individual, that is, at the level of interlocutors interacting and adapting continuously and reciprocally. This is characterized by iteration rather than linearity (De Bot, Lowie, & Verspoor, 2007). As a result of this process of constant moment-to-moment co-adaption, more complex language structures emerge from interactions over time. These adaptive processes of language use can be understood through a complex dynamic systems view (Cameron & Larsen-Freeman, 2007; Van Geert, 1991). Although teachers' and students' discourse is bidirectional in nature (Bronfenbrenner & Morris, 2006; Sameroff & MacKenzie, 2003; Van Dijk & Van Geert, 2011; Van Dijk et al., 2013; Van Geert, Steenbeek, & Van Dijk, 2011), most of prior empirical studies have focused only on the unidirectional relations between teacher characteristics and children's test results (e.g., Dickinson & Tabors, 2001; Huttenlocher et al., 2002). In contrast, dynamic, bidirectional adaptation processes can only be studied in real-time interactions. Recently, the relevance of studying real-time classroom interactions has been emphasized, as these interactions contribute significantly to learning and development (Dickinson & Neuman, 2007; Howes et al., 2008; Mashburn et al., 2008). Still, far too little attention has been paid to observational classroom studies that address microlevel interactions. For this reason, the underlying short-term bidirectional dependency between the language use of the teacher and that of the students is largely unknown.

A notable exception to this research literature is a study on language development in classroom settings by Justice, McGinty, Zucker, Cabell, and Piasta (2013). Using sequential analyses of moment-to-moment interactions, these authors revealed a clear interdependence between teachers and students in terms of the language complexity displayed during conversations in naturalistic preschool classrooms. Their finding that teachers were guided by the complexity of their students' utterances immediately preceding the teachers' own utterances was a particularly significant contribution to the existing literature. These findings support the idea that a transactional language dynamic

exists within the preschool classroom environment, such that the complexity of teachers' language use is influenced by and also influences the complexity of students' language use on a moment-by-moment basis. In naturalistic home settings, Huttenlocher, Waterfall, Vasilyeva, Vevea, and Hedges (2010) also found a similar bidirectional relationship with regard to vocabulary. This suggests a mutual process where children acquire words from caregivers, and caregivers are influenced by children's vocabularies. However, these bidirectional associations have not been found for syntactic structures, as shown, for instance, by Huttenlocher et al. (2010) who investigated bidirectional properties of language use over an extended period of time (multiple caregiver–child interactions), not within interactions, as in the study of Justice et al. (2013).

In their study, Justice et al. (2013) called for further research into bidirectional relations in teachers' and students' language across other contexts, in combination with a focus on stimulating teacher behavior. Although their results have indeed revealed bidirectional properties of language use in (preschool) classroom interactions, their study has not addressed language use in the context of science lessons, a context that is particularly important for advancing language learning. In the current study, we therefore aimed to explore the dynamics of early elementary science discourse and to understand how the co-adaptation processes of teachers and students develop within the context of early elementary science lessons. We used observational methods to capture the language use unfolding in real time, which is essential for understanding the underlying dynamics of the interaction (Bakeman & Quera, 2011). The real-time verbal interaction sequences were examined using sequential analysis in the context of early science lessons with the ultimate goal of gaining insight into the teacher–student language dynamics.

Adaptation Processes of Novice Versus Experienced Teachers

Many studies have emphasized the crucial role of adaptive processes in the language development of children (e.g., Snow, 1972; Van Dijk & Van Geert, 2011; Van Dijk et al., 2013). Language can be seen as an ordered, interdependent, and meaningful sequence of utterances of the individuals in a specific interactional context (e.g., teacher–student discourse during a science lesson). Typically, the utterances of the interacting partners are not independent, but are co-constructed and coordinated to create meaning and understanding. Both teachers and students co-adapt their individual utterances to each other and build upon each other's verbal expressions to co-construct knowledge (Ensing, Van der Aalsvoort, & Van Geert, 2012; Van Geert & Steenbeek, 2005). Teachers might flexibly modify their speech—and might progressively increase

the complexity of their language use—to fit the language complexity expressed by their students, and these abilities constantly change in interactions in the classroom (Corno & Snow, 1986). Adaptation processes require a lot of flexibility. This flexibility emerges from experience and knowledge of a great variety of classroom situations (Randi & Corno, 2005). Compared to experienced instructors, relatively inexperienced teachers (novice teachers or teachers in training) have more limited frameworks of classroom interaction, making it harder for them to adapt to the abilities of their students. This often leads to teaching in a way that is more rigid and relies more on procedural structures (Sternberg & Horvath, 1995).

It becomes clear from the literature addressing novice teachers' conceptions of teaching science that they often face great challenges. For instance, these challenges concern engaging students in science lessons, organizing and presenting instructions, and understanding and interpreting student responses (Schwarz et al., 2008), as well as recognizing that teachers have more sophisticated ideas than can be put into practice in a classroom (Bryan & Abell, 1999). As a result, novice teachers tend to overemphasize the use of hands-on activities (Abell, Bryan, & Andersen, 1998). In terms of language use, McIntyre and Hellsten (2004) found that the number of years of teaching experience was positively associated with teachers' knowledge about language form and language content. In sum, compared to novice teachers, experienced teachers are expected to be more flexible with linguistic scaffolding and adaptation in early science lessons, because these processes require educational practice and skills. Differences between experienced and novice teachers, which possibly reflect different teacher–student interaction dynamics, might also be reflected in the language use of students.

The Current Study

The current study focused on language use in terms of syntactic complexity and lexical density in the moment to moment interactions between teachers and students in naturalistic science lessons. Our goal was to determine whether there was an underlying bidirectional relation in language interaction and, if such a relation existed, to better understand its properties, including potential differences between experienced teachers and novice teachers. In addition, we wished to explore whether open-ended teacher questions evoked complex and lexically dense language use in students.

By examining teacher–student interactions at the utterance level, we aimed to identify types of interaction that support students' complex language use. We anticipated that such skills would likely be most evident at moments in

which the teacher was, on the one hand, using complex and dense language and, on the other hand, eliciting complex language from students by asking them stimulating open-ended questions. Based on the review of existing literature, we hypothesized the existence of underlying bidirectional relations regarding the language use of teachers and students, whereas these relations would be stronger for experienced teachers, compared to novice teachers. The following research questions were addressed:

1. What characterizes teacher–student interactions in early science lessons in terms of production output, average sentence length, causal connectives, and lexical diversity? What are some of the differences between experienced and novice teachers with regard to these variables?
2. Do both groups of teachers and their students demonstrate bidirectional sequential dependencies regarding syntactically complex utterances?
3. Do both groups of teachers and their students demonstrate bidirectional sequential dependencies regarding utterances with dense content-specific vocabulary?
4. Do open-ended teacher questions lead to more syntactically complex utterances by students as well as more utterances with dense content-specific vocabulary?
5. What are some of the differences between experienced and novice teachers regarding these sequential relations?

Method

Participants

Twenty-two experienced teachers (all female) and eight novice teachers² (seven female, one male) with a small group of students (3–6 students per teacher) participated voluntarily in this study. The experienced teachers had an average of 16 years of teaching experience (*range* = 1–38, *SD* = 11). The novice teachers were all teachers in training enrolled in the general teacher training bachelor program at the Hanze Applied University in Groningen (minor course in early elementary education); they had 4 years of teacher training experience each based on yearly internships and had followed a short theoretical course on teaching science in elementary school. Both the experienced and novice teachers had no (or very limited) experience in teaching science, as science education is not part of the standard elementary school curriculum in the Netherlands for this age group, which was the main reason for setting up the Curious Minds project. At the start of the data collection, the teachers were between 22 and 60 years old ($M = 42$, $SD = 11$), and the novice teachers were

between 21 and 26 years old ($M = 23$, $SD = 2$). The participating students ($N = 140$) were between 4 and 6 years old ($Mode = 5$ years) and were nearly evenly distributed according to gender (56% boys vs. 44% girls). All teachers and students were native speakers of Dutch. According to the teachers, none of the participating students had any notable developmental problems.

This study was part of a larger project involving teacher intervention called “Language as a Tool,” targeting language use in science lessons. All participants signed up voluntarily, suggesting that all teachers were motivated to learn about how to teach science. The current study targeted only the first two of eight science lessons (each lasting 15–40 minutes), which provided baseline measurements. The data were collected systematically (videotaped) in naturalistic classroom situations during small group science lessons. The teachers were instructed to select 3–6 students varying in age, gender, and cognitive level in order to achieve a fair representation of the classroom as a whole. The same students participated during both observations. The teachers were recruited from schools in a regional collaboration project about science education. The teachers and parents of the participating students gave informed consent before the start of the study, and all procedures conformed to existing ethical guidelines.

Transcription Procedure

The videotaped lessons were transcribed by the first author and a trained research assistant, following the Codes for Human Analysis of Transcripts conventions (MacWhinney, 2000). The unit of transcription was the utterance. Utterance boundaries were determined based on turn taking, pauses, and intonation patterns (Brown, 1973). Partly or completely unintelligible utterances were excluded from the analysis. No distinction was made between individual students, such that the speaker was identified as either a teacher or a student.

Measures

Several general interaction and language measures were calculated to provide context for sequential analyses. An overview of the methods used to obtain these measures is provided in Table 1.

Syntactic Complexity

In order to capture the syntactic complexity of the teachers’ and students’ language, each utterance was coded using a coding system with mutually exclusive and exhaustive categories. The coding scheme was based on the description of sentence complexity provided in Huttenlocher et al. (2002) and the version of the Huttenlocher et al. coding scheme used by Justice et al. (2013).

Table 1 Overview of general interaction and language measures with corresponding methods used to obtain these measures

Measure	Method
General interaction measures	
MLU	Command <i>mlu</i> in CLAN
Proportion student utterances	Command <i>mlu</i> in CLAN
Proportion open-ended teacher questions	Number of open teachers' questions relative to all teacher utterances
Language measures	
Lexical diversity	Command <i>vocd</i> in CLAN
Number of causal connectives	Calculated number of Dutch connectives <i>omdat</i> , <i>zodat</i> , <i>doordat</i> , <i>daardoor</i> , <i>hierdoor</i> , <i>waardoor</i> , <i>daarom</i> , <i>dus</i> and <i>want</i> , which are best approximated in English by variations of <i>because</i> , <i>therefore</i> and <i>so</i> using command <i>freq</i> in CLAN

Each utterance was coded for sentence complexity using the following codes: (0) the utterance contained no clause, (1) the utterance contained one clause (simple sentence), or (2) the utterances contained multiple clauses (complex sentence). Table 2 provides an overview of the codes, including some examples of teacher and student utterances with corresponding codes.

Utterances were based on turn taking, pauses, and intonation patterns; therefore, it occurred several times that utterances started with “and,” which usually functions as a coordinating conjunction. Due to the informal character of oral language use, such cases were not coded as complex utterances. Quite often an utterance starting with “and” was not preceded by an utterance of the same speaker, which supported our decision. When “and” was used by the same speaker in the middle of an utterance to coordinate two utterances, then the utterance was coded as complex. Incomplete sentences were included among complex sentences if they were a response to, for instance, a teacher's question. When the teacher asked, “Why does the stone sink?” and a student answered, “Because it is heavy,” the student's utterance was coded as a complex utterance. In such cases, the teacher's and student's utterance together form a complete complex sentence: “The stone sinks, because it is heavy.”

After coding each utterance, the proportion of complex utterances was computed by dividing the number of complex utterances by the total number of utterances (including the 0 codes). For the students, the proportion of complex

Table 2 Coding scheme for syntactic complexity with examples of teachers’ and students’ utterances and corresponding codes

Code	Teacher	Code	Students
No clause (0)	What about you? Really?	No clause (0)	Red and blue. Yes.
Simple (1)	What causes sound? And the clay ball sinks to the bottom.	Simple (1)	It floats. This marble rolls down very fast.
Complex (2)	You think that when I hit this very hard then the container will fall off the table. We are going to count down because the other time some children let go of the balloon earlier.	Complex (2)	When you open the cap then it floats but then also the water comes in. Well, the air vibrates and that makes noise.

Note. Examples (from the Dutch transcripts) are literal translations into English.

utterances was a measure of syntactic competence, which indicated the extent to which students expressed relations captured by complex syntax, independent of the total amount of speech they produced (see Huttenlocher et al., 2002). The teachers’ proportion of complex utterances indicated how such sentences were typically used to describe particular situations in science lessons. For the purpose of the sequential analyses, the codes of syntactic complexity per utterance were used.

Lexical Density of Content-Specific Words

Lexical density of content-specific words³ was operationalized as an adapted measure of lexical density, which typically refers to the proportion of lexical items relative to all words in a sample. Our measure was intended to reflect the number of lexical content-specific items per utterance. This captured how explicit and dense the information was that teachers and students discussed in science lessons. Lexical density is recognized as significantly contributing to the complexity of language, as proposed by Halliday (1985). Following Halliday, all lexical items (i.e., excluding function words) were included in the measure so that nouns and verbs that indicate specific actions or descriptions, adjectives that specify objects or actions, and adverbs that are derived from adjectives were counted. According to Halliday, it was unimportant what the exact boundaries of lexical items are, as long as the decision rules are followed consistently.

This approach was adopted for our coding scheme, with the exception that the number of lexical words per utterance was computed instead of converting this number into a proportion. This decision was made to enable further sequential analysis at an utterance level. Because the intent was to investigate sequences at an utterance level, it was not possible to include diversity measures, such as vocd and MTLD, as these measures require a large number of utterances to compute an estimate of lexical diversity that can be reliably interpreted.

The coded lexical items reflected the extent to which teachers and students used lexically dense language, but only when those words were also content and task related. In the context of early elementary science lessons, lexical items used to describe the materials, objects, and concepts (e.g., metal, balloon) are important vocabulary in addition to general academic words (e.g., hypothesis, explanation, gravity). As the goal of the coding was to capture the number of content- and task-related words, only lexical items that were related to the content or the task (e.g., magnet, aquarium, clay, water, predict, heavy) were coded, while words that were not content or task specific (e.g., thing, do, make, put) were excluded. The coding scheme included the following codes for categorizing the utterances based on the density of word use: (0) no content words, (1) one content word, and (2) multiple content words. Initial versions of the coding scheme included categories for up to four or more content words; however, the number of categories was eventually reduced based on the very few instances belonging to the highest categories in the transcripts. Table 3 lists examples for each of the coding categories.

Open-Ended Teacher Questions

In order to test whether the extent of teachers' open-ended questions was associated with students' utterances and the complexity/explicitness of their responses, each teacher utterance was coded according to the following codes: (0) no question, (1) closed-ended question, or (2) open-ended question. The coding protocol was based on the coding scheme of de Rivera et al. (2005). Table 4 provides an overview of these codes with corresponding examples.

Coding Reliability

Interrater reliability for the application of the coding conventions was calculated for 20% of the transcripts for syntactic complexity and word use and for 10% of the transcripts for open-ended questions. Interobserver agreement was considered almost perfect for all measures (sentence complexity: 89%; word use: 82%; questions: 95%). Cohen's kappa calculated to determine the consistency of coding among the two observers (Landis & Koch, 1977) revealed

Table 3 Coding scheme for lexical density with examples of teachers’ and students’ utterances and corresponding codes

Code	Teacher	Students
No content words (0)	You put this on that.	You don’t need to do it like this.
One content word (1)	Could you do that again?	Yes, this one.
	Do you want to put it like this in the water or like this?	That they were vibrating .
Multiple content words (2)	What do you think the marble will do when you put it in this one?	It will float .
	When you put another paper in the same color next to this one and you draw another dot then you can compare what has actually changed .	I think that the syrup lifts up the water and oil and then it goes &uh and then the whole table will overflow .

Note. Examples (from the Dutch transcripts) are literal translations into English.

substantial consistency for word use ($\kappa = .72$) and almost perfect consistency for both sentence complexity ($\kappa = .83$) and open-ended teacher questions ($\kappa = .91$).

Procedure

The teachers were asked to give a regular science lesson on a subject of their own choice for the duration of 15–20 minutes. The choice of the topic was left free in order to encourage teachers’ self-efficacy. Upon request, teachers were given some suggestions for easily accessible topics (e.g., <http://www.proefjes.nl>). Most teachers chose subjects involving crafting, designing, floating and sinking, air pressure, senses, sound, or marble tracks. Each videotaped lesson lasted between 11 and 39 minutes, of which the first 2.5 minutes (introduction), the middle 5 minutes (which often involved conducting an experiment), and the last 2.5 minutes (conclusion) were coded. This decision was made to allow comparisons between the different teachers in terms of content that was not affected by lesson duration.

Data Analyses
Permutation Tests

For further analysis, permutation tests were used, as the assumptions of traditional statistics could not be met due to the small sample size (Todman &

Table 4 Coding scheme and examples for questions used by teachers

Code	Type of expression	Example
No question (0)	Utterance related to instructions, classroom management, information and questions that are not related to the content.	<ul style="list-style-type: none">• Please put the marble on the track.• Keep your eyes on the table.• Gravity is [. . .].
Closed question (1)	Question that constraints the student's response because there is only one correct or acceptable answer, such as yes/no questions, multiple-choice questions, naming questions.	<ul style="list-style-type: none">• Does it float?• Will the rice also dance, or do you think it will stay at the bottom of the glass?• So you say it will . . . ?• What is this called?
Open-ended question (2)	Question that does not constrain the student's response because a number of different answers is acceptable (not one correct answer), such as open-ended questions, thought-provoking questions, elaborations questions.	<ul style="list-style-type: none">• What just happened with the oil?• What do you think will happen when [. . .]?• Why do you think that [. . .]?• How does that work then?

Note. Examples (from the Dutch transcripts) are literal translations into English.

Dugard, 2001). A Monte Carlo analysis (Good, 2006) is a nonparametric test that evaluates the null hypothesis that the probability of the specific association between the variables under study is based on chance alone. To achieve this, data are randomly sampled multiple times in order to determine whether the empirically found value or difference (i.e., between groups) could be expected based only on chance. The Monte Carlo permutation test provides an estimation of the exact *p* value, which is the probability that the same or a greater difference is found if the null hypothesis is supported. The greater the number of permutations, the closer this estimation comes to the exact value (see Gigerenzer, 2004; Schneider, 2015). Monte Carlo analyses were performed in Microsoft Excel in combination with PopTools (version 3.2). As significance scores are not directly linked to practical significance (Sullivan & Feinn, 2012), effect size values were computed using Cohen's *d*. Based on Cohen's (1992) classification, an effect size of .20 (or −.20) is small, an effect size of .50 (or −.50) is medium, and an effect size of .80 or (−.80) is large. To determine

whether the data provided strong, weak, or no support for our hypotheses, several combinations of p values and effect sizes were evaluated. Only when the empirically found value was associated with a very small probability of being produced under the null hypothesis (i.e., with a p value smaller than .05 and an effect size greater than .50 or $-.50$) were the findings interpreted as strong evidence to support the conclusion that the empirical value exceeded one based on chance alone. Empirical results with p values between .05 and .10 and an effect size greater than .50 (or $-.50$) were interpreted as providing weak support for rejecting the null hypothesis. Results with relatively small effect sizes (below .50 or $-.50$, whatever the p value) or p values above .10 (whatever the effect size) could be understood as providing no support for rejecting the null hypothesis. In addition, distributions of the sequential relations per group for each measure were inspected visually, using boxplots to indicate interindividual differences.

Comparison of General Measures

The general measures of language use for both groups (experienced and novice teachers) were compared using Monte Carlo analyses. First, the average score of the novice teachers was subtracted from the average score of the experienced teachers (mean difference). Second, the observed data of the experienced teachers and of the novice teachers were randomly sampled 10,000 times and, for each set of these sampled data, a difference between the two teacher groups was determined. This corresponded to the null hypothesis that there were no global differences between these groups, and thus that both groups stemmed from the same population. In a third step, the empirically found difference between the groups was compared with the simulated difference. This resulted in the probability that the same or a greater difference would be found if the null hypothesis were true, which was expressed as a p value. In addition, effect sizes describing the magnitude of association effects were computed.

Sequential Analysis

To examine spontaneous language use of teachers and students during science lessons as it unfolded sequentially in time, sequential analysis was used. Sequential analysis is a technique that captures patterns and contingencies in data sequences (Bakeman & Quera, 2011). The data were coded in Microsoft Excel and, for the purpose of this analysis, all codes were collapsed into one column that included the codes for both teachers' and students' utterances. The codes for adjacent utterances (sequences) were aligned by shifting the first column one row down; the first column represented a source behavior, and the

second column stood for the target behavior. Subsequently, transition matrices were calculated using a macro in which each successive utterance code was scanned for a source utterance code. A transition matrix thus summarized co-occurrences of source and target behaviors (contingency) in absolute numbers. Then, the frequencies of contingent behaviors were computed, reflecting the immediate sequential relations between teachers' and students' utterances (and vice versa) as observed in real-time classroom interactions. Incomplete or (partly) unintelligible utterances, which followed source utterances in 6.9–13.5% of the cases and which were calculated with an extended version of the transition matrix, were removed before further analysis. This procedure was followed for every teacher–student dyad so that the mean transition matrix and corresponding frequencies could be computed.

A Monte Carlo analysis was performed next to determine the probability that the empirically derived sequences were based on chance alone. First, the data per teacher–student dyad were sampled (without replacement) 1,000 times so that they were distributed randomly over both columns. For each of the randomly arranged series, the transition matrices and corresponding frequencies were recalculated, over which an average sequential relation was computed. This simulated the null hypothesis that the sequences between teachers and students were random and unrelated to each other. After this, the sequential relation observed in the data was compared with the sequential relation in the simulated samples, which resulted in a *p* value associated with the probability that the observed difference (or a value larger or smaller than the observed one) occurred under the null hypothesis. Additionally, effect size values were computed to allow for meaningful interpretations of the results.

The procedure used for examining whether there was a relation between open-ended teacher questions and students' language use was similar to the procedure described above. In this case, however, of interest was how often open-ended questions were followed by complex sentences and sentences with multiple content words. To determine whether experienced teachers differed from novice teachers with regard to the sequential relations, a third set of Monte Carlo permutation tests was performed. For this final comparison, a mean difference between the percentage score (reflecting the sequential relation) for the novice teachers was subtracted from the percentage score for the experienced teachers. To allow for comparisons of the frequencies in the transition matrices, a simulated dataset was created by sampling the scores of the experienced and novice teacher groups 10,000 times. This simulated the null hypothesis that the empirical sequential relations for both groups were similar. The mean difference between the experienced and novice teachers observed in

Table 5 Summary for measures of general interaction and language for experienced and novice teachers

Measure	Experienced teachers		Novice teachers		Monte Carlo	Effect size
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>p</i>	<i>Cohen's d</i>
MLU	5.75	0.75	5.92	0.50	.21	−0.27
Diversity	75.14	9.95	72.19	6.93	.13	0.34
Causal connectives	9.91	4.54	10.19	5.44	.42	−0.06

Table 6 Summary for measures of general interaction and language for the students of experienced and novice teachers

Measure	Experienced teachers		Novice teachers		Monte Carlo	Effect size
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>p</i>	<i>Cohen's d</i>
MLU	3.76	0.83	3.72	0.64	.44	0.05
Proportion student utterances	0.43	0.09	0.36	0.09	< .01	0.79
Diversity	51.25	10.73	52.90	13.16	.31	−0.14
Causal connectives	3.61	3.47	3.94	4.01	.38	−0.09

the empirically derived data was then compared with the mean difference in the randomly simulated samples, to determine how often the observed difference occurred in these random samples. This resulted in a *p* value associated with the probability that the observed difference (or a value larger or smaller than the observed one) occurred under the null hypothesis. Additionally, effect size values were computed to estimate the magnitude of differences in sequential relations between the two teacher groups.

Results

General Measures

Tables 5 and 6 summarize measures of general interaction and language use for both experienced and novice teachers and their students. Monte Carlo permutation tests revealed no notable differences between the experienced and novice teachers, with one exception: The proportion of student utterances was higher in classrooms of experienced teachers, compared to those of novice teachers ($M_{\text{experienced teachers}} = .43$, $M_{\text{novice teachers}} = .36$, $p < .01$, $d = .79$).

Figure 1 Transition matrix displaying bidirectional sequential relations (in percentages) between syntactically complex utterances (SCU) of experienced teachers (E) and their students (S) and of novice teachers (N) and their students (S).

Sequential Relations: Syntactic Complexity

The second research question asked whether teachers and students showed temporal dependencies on each other's syntactically complex utterances. The first step toward answering this was to determine the number of complex utterances relative to the total number of utterances. On average, the percentages of complex utterances expressed by the experienced teachers ($M = 20.0$, $SD = 6.1$) and novice teachers ($M = 19.7$, $SD = 4.9$) were comparable ($p = .43$, $d = .06$). The students of novice teachers used more complex sentences ($M = 12.1$, $SD = 7.2$) than the students of experienced teachers ($M = 9.1$, $SD = 4.6$; $p = .04$, $d = -.49$).

Next, sequential analyses were performed to examine temporal relations between the syntactic complexity of teachers and students. The analyses showed that given a syntactically complex teacher utterance, on average, the probability that students would follow with a syntactically complex utterance was 6.5% for the experienced teachers and 7.9% for the novice teachers (see the transition diagram on the left in Figure 1). A Monte Carlo permutation test revealed that both empirical contingencies were stronger than expected by chance alone, based on a comparison with a simulated dataset ($p_{\text{experienced teachers}} < .01$, $d = .79$; $p_{\text{novice teachers}} < .01$, $d = .90$). The sequential analyses provided evidence that the students used complex utterances more often in response to complex teacher utterances than could be expected based on chance.

In the case of complex student utterances, on average, such utterances were followed by syntactically complex teacher's utterances in 25.2% of the cases for the experienced teachers and in 18.1% of the cases for the novice teachers (see the transition diagram on the right in Figure 1). A comparison of these temporal relations in the empirical data with the corresponding relations in a simulated sample showed strong evidence (greater than would be expected based on

Figure 2 Boxplots representing the distribution of sequential relations between syntactically complex utterances of experienced and novice teachers and their students as measured in individual classrooms.

chance alone) for a temporal relation between complex student utterances and contingent complex experienced teacher utterances ($p < .01$, $d = 1.47$). In the case of novice teachers, the Monte Carlo analysis revealed that the probability that the observed sequential relation had been produced by chance was slightly greater than the .05 benchmark ($p = .06$, $d = .93$), which provided weak support for a temporal relation.

The third analysis targeted interindividual differences in order to complement previous results and allow for interpretations of the global patterns described previously. From Figure 2, it can be seen that the variability seemed larger for the temporal relation between students' and experienced teachers' utterances than for the same relation between students' and novice teachers' utterances. In sum, the results revealed temporal dependencies between complex teacher utterances and complex student utterances for three of the four relations. There was weak support for the existence of a sequential relation between students' and novice teachers' complex utterances. Overall, the results provided support for the existence of an underlying bidirectional relation with regard to syntactic complexity. However, distribution measures pointed toward a large amount of interindividual variability.

Sequential Relations: Lexical Density of Content-Specific Words

The third research question concerned the existence of a bidirectional relation between dense vocabulary of teachers and students. The experienced teachers ($M = 28.6$, $SD = 8.2$) and their students ($M = 14.2$, $SD = 6.5$) produced more

Figure 3 Transition matrix displaying the bidirectional sequential relations (in percentages) between utterances with lexically dense content-specific vocabulary (LD = two or more content-specific lexical items, nLD = 0 or 1 content-specific lexical items) of experienced teachers (E) and their students (S) and of novice teachers (N) and their students (S).

utterances with dense vocabulary, compared to the novice teachers ($M = 13.3$, $SD = 5.3$) and their students ($M = 8.6$, $SD = 6.8$; $p_{\text{teachers}} < .01$, $d = 2.21$; $p_{\text{students}} < .01$, $d = .84$). The sequential analyses showed that given a dense teacher utterance, on average, the students followed with a dense utterance in 6.2% of the cases for the experienced teachers (see the transition diagram on the left in Figure 3). A Monte Carlo permutation test revealed that the empirical sequence was not different from the simulated sequence ($p = .22$, $d = .14$), which means that student utterances with dense vocabulary were not contingent upon experienced teachers' utterances with lexically dense content-specific vocabulary. For the novice teachers, the empirical data provided strong evidence for a sequential relation between dense teacher utterances followed by dense student utterances. This occurred in 5.7% of the cases, which was larger than could be expected under the null hypothesis ($p = .03$, $d = .60$).

When a student produced an utterance with dense vocabulary, on average, this utterance was followed by a dense teacher utterance in 25.9% and 16.1% of the cases for the experienced and novice teachers, respectively. This was larger than could be expected under the null hypothesis ($p_{\text{experienced teachers}} < .01$, $d = 1.18$, $p_{\text{novice teachers}} = .02$, $d = 1.33$). Figure 4 illustrates the variation between individuals with regard to utterances with dense vocabulary. In particular, the boxplots display large differences for the responses of experienced teachers to their students. In sum, these results provide some support for bidirectional relations with regard to the use of lexically dense vocabulary. An important finding was that lexically dense teacher utterances were more contingent on lexically dense student utterances than vice versa, particularly for the experienced teachers. The results also showed clear interindividual differences, especially between the reactions of experienced teachers to their students.

Figure 4 Boxplots representing the distribution of sequential relations between utterances with lexically dense content-specific vocabulary of experienced and novice teachers and their students as measured in individual classrooms.

Eliciting Sophisticated Language of Students

The fourth research question asked whether there were sequential dependencies between open-ended teacher questions and the complexity of student language in terms of syntax and dense vocabulary. Over one third of the teacher utterances were devoted to questions ($M_{\text{experienced teachers}} = 35.5$, $SD = 8.8$; $M_{\text{novice teachers}} = 36.1$, $SD = 8.4$). Novice teachers asked more open-ended questions than experienced teachers ($M_{\text{experienced teachers}} = 9.8$, $SD = 4.0$, $M_{\text{novice teachers}} = 14.4$, $SD = 5.3$; $p < .01$, $d = -.93$).

The next analysis examined temporal patterns of whether these open-ended teacher questions elicited syntactically complex student responses. The sequential analyses (see Figure 5) showed that given an open-ended teacher question, on average, the probability that students would follow with a syntactically complex utterance was 17.4% for the experienced teachers and 12.2% for the novice teachers. A Monte Carlo permutation test revealed that this probability was greater than would expected by chance alone, based on a comparison with a simulated dataset for the experienced ($p < .01$, $d = 1.68$) and novice ($p < .01$, $d = 1.68$) teachers. These findings provided strong evidence for the hypothesis that open-ended teacher questions evoke complex student utterances in both teacher groups. Figure 6 displays the variation between individuals, which seemed larger for the group of experienced teachers, compared to the novice teachers.

The following analysis targeted the sequential relation between open-ended teacher questions and student utterances with dense vocabulary. The

Figure 5 Transition matrix displaying the sequential relations (in percentages) between open-ended teacher questions (T_{open}) of experienced teachers (E) and novice teachers (N) and complex student responses ($S_{complex}$).

Figure 6 Boxplots representing the distribution of sequential relations between open-ended teacher questions and complex student utterances as measured in individual classrooms of experienced and novice teachers.

transition diagram in Figure 7 shows that 19.8% of the students of experienced teachers and 6.3% of the students of novice teachers employed dense vocabulary in their responses to open-ended teacher questions. The Monte Carlo analysis indicated that these observed sequences were larger than those associated with the simulated null hypothesis model for both the experienced ($p < .01$, $d = 1.78$) and novice ($p < .01$, $d = 1.32$) teachers, suggesting that open-ended teacher questions are more often followed by student utterances with dense vocabulary than what would be expected based on chance.

Figure 7 Transition matrix displaying the sequential relations (in percentages) between open-ended questions (T_{open}) of experienced teachers (E) and novice teachers (N) and student utterances with lexically dense content-specific vocabulary (LD = two or more content-specific lexical items, nLD = 0 or 1 content-specific lexical items).

Figure 8 Boxplots representing the distribution of sequential relations between open-ended teacher questions and dense student utterances as measured in individual classrooms of experienced and novice teachers.

Figure 8 shows the distributions of the temporal relations for both teacher groups. Again, the experienced teachers showed more variation between individuals, compared to the novice teachers. Taken together, these analyses showed that there was strong evidence for sequential relations between

open-ended teacher questions and complex and dense student responses for both teacher groups.

Experienced Versus Novice Teachers

The final research question addressed potential differences between experienced and novice teachers. Table 7 provides a summary of the sequential relations for both groups, as well as comparisons of these relations between groups. Overall, comparisons between experienced and novice teachers provided evidence for the hypothesis that the relations were stronger in the experienced teacher group, compared to the novice teachers. This was particularly the case for the utterances of experienced teachers in reaction to student utterances, indicated by weak evidence regarding syntactic complexity ($p = .06$, $d = .71$) and strong evidence regarding utterances with dense vocabulary ($p < .01$, $d = 1.05$). Open-ended questions of experienced teachers elicited more complex and lexically dense student responses, compared to novice teachers' questions, which was strongly supported by the Monte Carlo analysis for word use ($p < .01$, $d = 1.59$), but not for syntactic complexity ($p = .12$, $d = .56$).

Discussion

Several previous studies have stressed the importance of integrating language learning and science education (Conezio & French, 2002; French, 2004; French & Peterson, 2009; Glass & Oliveira, 2014; Patrick et al., 2008). Our findings specifically emphasized the relevance of modeling complex language in interaction with students and eliciting complex language from students by asking open-ended questions. Despite our teachers' lack of experience in teaching science, we found indications of mutual adaptation when it comes to complex and lexically dense language in the teacher–student interaction during these early science lessons. More specifically, we found evidence for bidirectional temporal relations between the complexity and density of teachers' and students' language. Complex and dense language use of students was most evident at moments in which the teacher used complex and dense language and encouraged the students to give elaborate answers by asking open-ended questions.

Insights into the underlying dynamics and structure of the language interaction during science lessons are of great importance in the context of language learning. The current study contributed to the knowledge on the dynamics in the real-time teacher–student dialogue by using sequential analysis. The findings of bidirectional relations with regard to complex and dense language use

Table 7 Overview of the sequential relations, with a summary of the corresponding *p* values (tested against random sample), and comparisons of these relations for experienced and novice teachers

Measure	Initial utterance	Experienced teachers			Novice teachers			Experienced vs. novice teachers		
		<i>M</i> (<i>SD</i>)	<i>p</i>	<i>d</i>	<i>M</i> (<i>SD</i>)	<i>p</i>	<i>d</i>	<i>p</i>		<i>d</i>
Syntax	Teachers	6.5 (4.8)	< .01	0.79	7.9 (6.2)	< .01	0.90	.74		−0.25
	Students	25.2 (12.4)	< .01	1.47	18.1 (6.6)	.06	0.93	.06		0.71
Density	Teachers	6.2 (3.9)	.22	0.14	5.7 (5.3)	.03	0.60	.40		0.11
	Students	25.9 (10.4)	< .01	1.18	16.1 (8.1)	.02	1.33	< .01		1.05
Question-syntax	Teachers	17.4 (11.3)	< .01	1.68	12.2 (6.8)	< .01	1.68	.12		0.56
Question-density	Teachers	19.8 (10.9)	< .01	1.78	6.3 (5.1)	< .01	1.32	< .01		1.59

emphasized the value of investigating immediate, moment-by-moment sequences in teacher and student language during early elementary science interactions. In addition, results suggested that open-ended questions can be seen as a driving mechanism in the context of language learning within early elementary science education, as teachers' use of open-ended questions evoked more complex and dense student responses. An implication for teachers is that they are encouraged to pose open-ended questions—as opposed to closed-ended questions which often elicit only a single word—so that students are stimulated to give more elaborate and complex responses.

Syntactic Complexity

An analysis of the real-time verbal interaction revealed that, on average, 20% of the teacher utterances (experienced and novice teachers) were syntactically complex, and 9% (for experienced teachers) and 12% (for novice teachers) of the student utterances were complex. Although these percentages seem low, they are in line with those shown in previous work (Huttenlocher et al., 2002; Justice et al., 2013). The sequential analyses provided some evidence for the existence of a bidirectional relationship between teachers' and students' use of syntactically complex language, which means that teachers and students appeared sensitive to each other's use of complex sentences. We found strong evidence supporting this relationship in the experienced teacher group and weak support for the existence of this bidirectional relation in the novice teacher group. Earlier multivariate analyses have revealed associations between the syntactic complexity of teachers' and students' language (Huttenlocher et al., 2004; Vasilyeva et al., 2006), but these analyses did not allow researchers to demonstrate the bidirectional dynamics of complex language use, nor were associations between variables studied on the micro level, which is the level of real-time teacher–student interactions. For instance, Huttenlocher et al. (2002) found no relationship between the complexity of teachers' syntax and the syntactic skills of students at the start of the school year (although they did find such relationships during the school year), whereas our analysis of consecutive utterances within the interaction showed bidirectional relations between teachers' and students' use of syntactically complex sentences. The microlevel analyses conducted in the current study revealed that teachers tended to imitate the level of syntactic complexity of their students' language in immediately adjacent utterances. This tendency was stronger than the tendency of students to imitate the level of syntactic complexity of their teacher's utterances. These results are consistent with findings of Justice et al. (2013) in general preschool lessons.

The focus of the current study was on teacher–student interactions, which is important for language learning because it addresses the nature of the instructional input from teachers—in contrast to many studies focusing on parental input (e.g., Dale & Spivey, 2006; Danis et al., 2000; Huttenlocher et al., 2002)—and the corresponding language output of students (and vice versa). For the acquisition of complex sentence structures, it is important for children to hear linguistic structures in a variety of contexts in order to become familiar with these structures and to ultimately master them. Science lessons provide a well-suited context for students to become more proficient in using complex syntax to express complex ideas, as this requires exposure to various ways in which sentences can be connected through combining clauses and through the use of conjunctions to express particular relations between clauses. An important role of teachers, which they should be aware of, is thus to introduce complex linguistic structures during early elementary science lessons (Lemke, 1990; Wong et al., 2002). This means that teachers need to use modeling strategies in order to expand their students’ oral language skills and facilitate the development of sophisticated language.

This study showed that the level of syntactic complexity was somewhat greater for student utterances (and stronger for students of experienced teachers) with regard to the syntactic complexity of teachers’ responses, compared to the contingency in syntactic complexity between teachers’ utterances and students’ responses. Many researchers have proposed that input of a more knowledgeable conversation partner, such as a parent or teacher, is crucial for language learning (e.g., Dickinson & Smith, 1994; Girolametto et al., 2003; Huttenlocher et al., 2004; Snow, 1983; Vasilyeva et al., 2006); however, the current analyses showed that language use and language learning are characterized by bidirectionality in interaction. In addition to creating awareness of teachers’ own language use (Wong et al., 2002), it is important to inform teachers about the bidirectional nature of language use. This might help teachers to improve their own skills in listening to the responses of their students, in terms of what students say and in particular how they express their ideas, and to enable teachers to elaborate on these responses accordingly.

Lexical Density of Content-Specific Words

The extent to which experienced and novice teachers and their students employed dense vocabulary varied largely, both between and within groups. In classrooms of experienced teachers, both teachers and students expressed more utterances with dense vocabulary, compared to classrooms of novice teachers. The results of the sequential analyses provided evidence for a bidirectional

relation in teacher–student language regarding word use in the case of novice teachers. Again, this relation was stronger for teachers’ responses to students than vice versa. This is particularly interesting because classical multivariate studies have demonstrated relations on a macro level between language input of adults and, for instance, children’s vocabulary outcomes (Dickinson & Smith, 1994; Girolametto et al., 2003; Snow, 1983). Huttenlocher et al. (2010) also found such bidirectional relationships over multiple interactions. However, on a micro level, we did not detect associations between lexically dense utterances of experienced teachers and consecutive dense student responses. It may be that some delayed impact or more global effects of vocabulary use exist, for example, of the types suggested by Girolametto et al. (2003) and Dickinson and Smith (1994).

Open-Ended Teacher Questions

The fourth research question concerned identifying whether open-ended teacher questions evoked more complex and lexically dense student utterances. Our findings indicated that in early science lessons, 35% of the teacher utterances were devoted to questions, and 10% and 14% were open-ended questions for experienced and novice teachers, respectively. These proportions corresponded well to the values reported by Lee and Kinzie (2012), and our results showed that open-ended teacher questions led to more complex and lexically dense student utterances for both teacher groups, which also replicated the qualitative results of Lee and Kinzie (2012) on eliciting complex and dense student responses. For example, it has been suggested that students adapt the complexity of their language use to match the linguistic demands of teachers’ questions (Danis et al., 2000; Zucker et al., 2010). These results are important because they show that open-ended teacher questions contribute to students’ development of more sophisticated language skills, which are ultimately required to successfully participate in science lessons. In recent research, we showed that questions of this type were also related to the use of more complex reasoning skills (Wetzels, Steenbeek, & Van Geert, 2016). These findings also have important implications for early elementary school teachers because open-ended questions can be seen as a driving mechanism within the context of science learning. By improving their questioning strategies, teachers become more proficient in eliciting complex student responses both in terms of reasoning (Wetzels et al., 2016) and language (as demonstrated in the current data set). In the end, students benefit from better teacher questioning strategies in the sense that they are given more and better opportunities for advancing in language development.

Our data also suggested that (even in first science lessons) open-ended questions elicited more complex and dense student responses, which is a good starting point for interventions, where the corresponding student responses could serve, subsequently, as opportunities for teachers to elicit, model, and reformulate complex and lexically dense language structures. This appears to be when students really learn why and how to use complex language formulated in a dense way, and such teacher behaviors help them organize and verbalize their thoughts and ideas about the content.

Experienced Versus Novice Teachers

The final question of this study related to the comparison of moment to moment processes between experienced and novice teachers. The findings indicated stronger bidirectional relations for the experienced teachers in the sense that their use of complex and lexically dense language was contingent on their students' use of complex and dense language. Still, in both groups, there were large differences between individuals regarding the extent to which teachers and students adapted to each other's language use. An interesting finding is that, generally, the novice teachers asked more open-ended questions than the experienced teachers. This finding could be attributed to the educational curriculum of the current generation of student teachers. Although neither group had taught science to young children before, the novice teachers had completed a mandatory theoretical course in elementary science education, whereas the experienced teachers had not. The difference may also be explained by the fact that the novice teachers had a different instructional perspective or a different initial level of content expertise in science.

Although the participating novice teachers did pose more open-ended questions than the experienced teachers, the percentages of open-ended questions that elicited more complex and dense language were larger in the case of the experienced teachers. This also implies that experienced teachers are likely more sensitive, in their responses, to their students' abilities (Corno & Snow, 1986). Novice teachers are said to teach in a more rigid way (Sternberg & Horvath, 1995) and to be more concerned with classroom management (Schwarz et al., 2008), which probably makes them less sensitive to their students' behaviors, including linguistic behaviors. This information is relevant in the context of language learning, particularly with respect to teachers' elicitation strategies. Apart from informing teachers about the value of open-ended questioning strategies in science education, it is of particular importance that teachers learn how to pose stimulating questions that are specifically tailored to their students' abilities, thereby enabling students to respond with elaborate and linguistically

complex answers. Teachers need to understand and connect with the language abilities of their students to help them develop more refined language skills, as the language of schooling is complex (Snow & Uccelli, 2009). Novice teachers may also simplify their vocabulary instead of presenting information in a dense way, which relates to the idea that teachers—and in our case novice teachers—often consider the language of science too difficult for their students (Kallery & Psillos, 2001). The differences between the experienced and novice teachers in this study were probably caused by the experienced teachers' more refined skills of adaptation (Corno & Snow, 1986), as they are equipped with more experience and knowledge of a greater variety of classroom situations, allowing them to adapt and scaffold more flexibly (Randi & Corno, 2005). Both the experienced and novice teachers in our study were relatively inexperienced in teaching science, but the results suggested that experienced teachers adjust more easily and are more responsive to teaching in this new situation. These findings provided an illustration of the adaptation processes in the short-term dynamics of real-time interaction (Steenbeek & Van Geert, 2005).

Limitations

With regard to the interpretation of the results, it is important to bear in mind that teachers were recruited on a voluntary basis, which possibly biased the participants to be particularly interested and highly motivated to teach science. Learning to teach science, or to integrate science and language learning, requires highly motivated teachers. However, motivation alone does not guarantee successful science teaching. This was precisely what we aimed to investigate here: Given sufficient motivation for teaching science, how successful are teachers in eliciting high-quality language from their students? One limitation of the current analysis of syntactic complexity is that no distinction was made within the category of complex sentences. Earlier versions of the coding scheme had distinguished between coordinated complex sentences and subordinated, relative, and adverbial clauses, but the results revealed very few instances in these categories of complex sentences. One likely reason for this was the young age of the students, as complex sentence structures were likely just emerging for children of that age. The distinction within the category of complex sentences is, however, an important issue for future research on student–teacher interaction in upper grades, as older students possess more advanced language and reasoning skills and they may be better able to linguistically link clauses to indicate relations between events.

This study was also in part limited by the chosen methodology of sequential analysis, which only considered immediate sequential relations. Typically, the

utterances of interaction partners are not independent, but are co-constructed and coordinated to create meaning and understanding. Therefore, sequential analyses provide more information than typical correlational designs, but the current results of course do not enable us to draw causal conclusions. For instance, we cannot be sure that a teacher used a complex utterance *because* a student had just uttered a complex utterance. The adaptation, of the type documented here, may occur at a subconscious level. Another limitation is that by applying the sequential analysis, which only considered immediate sequences of utterances, it was impossible to detect underlying structures over multiple utterances or the whole interaction. In verbal interaction, teachers and students co-adapt their individual utterances, and the probability that certain combinations of utterances would recur within and across multiple interactions increases, creating more predictable patterns of language use. In future research, it would be important to study the impact of multiple previous and multiple subsequent utterances to analyze such possible delayed effects. For instance, to respond to this need, we have used a cross-recurrence quantification analysis (Menninga, Van Dijk, Cox, Steenbeek, & Van Geert, 2016), which is a method that allows for investigating possible delayed effects and longer-term coordination between the language use of teachers and students.

Conclusion

In conclusion, we showed that complex utterances and lexically dense vocabulary occur relatively infrequently during early science lessons. Most importantly, we found support for a bidirectional relationship between teachers and students with regard to syntactic complexity and density of word use, which is important in the process of co-constructing scientific knowledge in young children. Our results also indicated that experienced teachers were better able to adapt to the language needs of their students, compared to novice teachers. In future research, it would be important to include (qualitative) measures that indicate whether teachers' complex utterances are reformulations of students' preceding utterances or are in fact teachers' actual responses to student language. Reformulations, such as expansions and recasts, have been shown to be effective strategies to improve young children's syntactic development (Snow & Ferguson, 1977). However, in order to co-construct content knowledge, teachers could, for example, also build on their students' complex utterances with complex responses as a way of co-creating meaning.

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Notes

- 1 The focus of this study is on kindergarten and the first grade of elementary school (children aged 4–6). For clarity, we will use the term early elementary throughout the manuscript to refer to this target group.
- 2 When it is not necessary to distinguish between novice teachers and experienced teachers, they are both referred to as teachers.
- 3 Though our measure lexical density of content-specific words is not identical to measures of lexical density, for the purpose of readability, we refer to this measure as density.

References

- Abell, S. K., Bryan, L. A., & Andersen, M. A. (1998). Investigating preservice elementary science teacher reflective thinking using integrated media case-based instruction in elementary science teacher preparation. *Science Education*, 82, 491–510. doi:10.1002/(SICI)1098-237X(199807)82:4491::AID-SCE53.0.CO;2-6
- Bakeman, R., & Quera, V. (2011). *Sequential analysis and observational methods for the behavioral sciences*. New York: Cambridge University Press.
- Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition*, 75, 13–25. doi:10.1016/S0010-0277(99)00081-5
- Bronfenbrenner, U., & Morris, P. A. (2006). The bio ecological model of human development. In W. Damon (Series Ed.) & R. M. Lerner (Vol. Ed.), *Handbook of child psychology (Vol. 1): Theoretical models of human development* (5th ed.; pp. 994–1028). New York: Wiley.
- Brown, R. (1973). *A first language: The early stages*. London: George Allen & Unwin.
- Bryan, L. A., & Abell, S. K. (1999). Development of professional knowledge in learning to teach elementary science. *Journal of Research in Science Teaching*, 36, 121–139. doi:10.1002/(SICI)1098-2736(199902)36:2121::AID-TEA23.0.CO;2-U
- Cameron, L., & Larsen-Freeman, D. (2007). Complex systems and applied linguistics. *International Journal of Applied Linguistics*, 17, 226–240. doi:10.1111/j.1473-4192.2007.00148.x
- Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112, 155–159. doi:10.1037/0033-2909.112.1.155
- Conezio, K., & French, L. (2002). Science in the preschool classroom: Capitalizing on children's fascination with the everyday world to foster language and literacy development. *Young Children*, 57, 12–18.
- Corno, L., & Snow, R. E. (1986). Adapting teaching to individual differences among learners. In M. C. Wittrock (Ed.), *Handbook for research on teaching* (3rd ed.; pp. 605–629). New York: Simon & Schuster Macmillan.
- Danis, A., Bernard, J. M., & Leproux, C. (2000). Shared picture-book reading: A sequential analysis of adult-child verbal interactions. *British Journal of Developmental Psychology*, 18, 369–388. doi:10.1348/026151000165751

- Dale, R., & Spivey, M. J. (2006). Unraveling the dyad: Using recurrence analysis to explore patterns of syntactic coordination between children and caregivers in conversation. *Language Learning*, 56, 391–430.
doi:10.1111/j.1467-9922.2006.00372.x
- De Bot, K., Lowie, W., & Verspoor, M. (2007). A dynamic systems theory approach to second language acquisition. *Bilingualism: Language and Cognition*, 10, 7–21.
doi:10.1017/S1366728906002732
- de Rivera, C., Girolametto, L., Greenberg, J., & Weitzman, E. (2005). Children's responses to educators' questions in day care play groups. *American Journal of Speech-Language Pathology*, 14, 14–26. doi:10.1044/1058-0360(2005/004)
- Dickinson, D. K. (2001). Large-group and free-play times: Conversational settings supporting language and literacy development. In D. K. Dickinson & P. O. Tabors (Eds.), *Beginning literacy with language: Young children learning at home and school* (pp. 223–255). Baltimore: Brookes.
- Dickinson, D. K., & Neuman, S. B. (Eds.). (2007). *Handbook of early literacy research* (Vol. 2). New York: Guilford.
- Dickinson, D. K., & Smith, M. W. (1994). Long-term effects of preschool teachers' book readings on low-income children's vocabulary and story comprehension. *Reading Research Quarterly*, 29, 105–122. doi:10.2307/747807
- Dickinson, D. K., & Tabors, P. O. (2001). *Beginning literacy with language: Young children learning at home and school*. Baltimore: Brookes.
- Ensing, A., Van der Aalsvoort, G. M., & Van Geert, P. (2012). How dynamic patterns of teacher-child interaction can provide insight in the learning potential of five year olds. In E. Hjørne, G. van der Aalsvoort, & G. de Abrie (Eds.), *Learning, social interaction and diversity: Exploring identities in school practices* (pp. 189–202). Rotterdam, Netherlands: Sense Publishers. doi:10.1007/978-94-6091-803-2_13
- French, L. (2004). Science as the center of a coherent, integrated early childhood curriculum. *Early Childhood Research Quarterly*, 19, 138–149.
doi:10.1016/j.ecresq.2004.01.004
- French, L. A., & Peterson, S. M. (2009). Learning language through preschool science. In C. Andersen, N. Scheuer, M. Pérez Echeverría, & E. Teubal (Eds.), *Representational systems and practices as learning tools* (pp. 77–92). Rotterdam, Netherlands: Sense Publishers.
- Gigerenzer, G. (2004). Mindless statistics. *The Journal of Socio-Economics*, 33, 587–606. doi:10.1016/j.soc.2004.09.033
- Girolametto, L., Weitzman, E., & Greenberg, J. (2003). Training day care staff to facilitate children's language. *American Journal of Speech-Language Pathology*, 12, 299–311. doi:10.1044/1058-0360(2003/076)
- Glass, R., & Oliveira, A. W. (2014). Science language accommodation in elementary school read-alouds. *International Journal of Science Education*, 36, 577–609.
doi:10.1080/09500693.2013.802057

- Good, P. I. (2006). *Resampling methods: A practical guide to data analysis* (3rd ed.). Boston: Birkhäuser.
- Halliday, M. A. K. (1985). *Spoken and written language* (1st ed.). Geelong, Australia: Deakin University.
- Halliday, M. A. K. (1993). Towards a language-based theory of learning. *Linguistics and Education*, 5, 93–116. doi:10.1016/0898-5898(93)90026-7
- Halliday, M. A. K., & Martin, J. R. (1993). *Writing science: Literacy and discursive power*. Pittsburgh, PA: University of Pittsburgh Press.
- Howes, C., Burchinal, M., Pianta, R., Bryant, D., Early, D., Clifford, R., et al. (2008). Ready to learn? Children's pre-academic achievement in pre-kindergarten programs. *Early Childhood Research Quarterly*, 23, 27–50. doi:10.1016/j.ecresq.2007.05.002
- Huttenlocher, J., Vasilyeva, M., Cymerman, E., & Levine, S. (2002). Language input and child syntax. *Cognitive Psychology*, 45, 337–374. doi:10.1016/S0010-0285(02)00500-5
- Huttenlocher, J., Vasilyeva, M., & Shimpi, P. (2004). Syntactic priming in young children. *Journal of Memory and Language*, 50, 182–195. doi:10.1016/j.jml.2003.09.003
- Huttenlocher, J., Waterfall, H., Vasilyeva, M., Vevea, J., & Hedges, L. V. (2010). Sources of variability in children's language growth. *Cognitive Psychology*, 61, 343–365. doi:10.1016/j.cogpsych.2010.08.002
- Justice, L. M., McGinty, A. S., Zucker, T., Cabell, S. Q., & Piasta, S. B. (2013). Bi-directional dynamics underlie the complexity of talk in teacher-child play-based conversations in classrooms serving at-risk pupils. *Early Childhood Research Quarterly*, 28, 496–508. doi:10.1016/j.ecresq.2013.02.005
- Kallery, M., & Psillos, D. (2001). Pre-school teachers' content knowledge in science: Their understanding of elementary science concepts and of issues raised by children's questions. *International Journal of Early Years Education*, 9, 165–179. doi:10.1080/09669760120086929
- Klein, E., Hammrich, P. L., Bloom, S., & Ragins, A. (2000). Language development and science inquiry: The Head Start on Science and Communication program. *Early Childhood Research and Practice*, 2, 1–22.
- Kramer, F., & Rabe-Kleberg, U. (2011). *Wissenschaftliche Untersuchungen zur Arbeit der Stiftung "Haus der kleinen Forscher."* Köln, Germany: Bildungsverlag EINS GmbH.
- Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33, 159–174. doi:10.2307/2529310
- Lee, Y., & Kinzie, M. B. (2012). Teacher question and student response with regard to cognition and language use. *Instructional Science*, 40, 857–874. doi:10.1007/s11251-011-9193-2
- Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.

- MacWhinney, B. (2000). *The CHILDES project: Tools for analyzing talk. Volume I transcription formats and programs* (3rd ed.). Mahwah, NJ: Erlbaum.
- Mashburn, A. J., Pianta, R. C., Hamre, B. K., Downer, J. T., Barbarin, O. A., Bryant, D., et al. (2008). Measures of classroom quality in prekindergarten and children's development of academic, language, and social skills. *Child Development*, 79, 732–749. doi:10.1111/j.1467-8624.2008.01154.x
- Massey, S. L., Pence, K. L., Justice, L. M., & Bowles, R. P. (2008). Educators' use of cognitively challenging questions in economically disadvantaged preschool classroom contexts. *Early Education and Development*, 19, 340–360. doi:10.1080/10409280801964119
- McIntyre, L. J., & Hellsten, L. A. M. (2004). The influence of teacher characteristics on teachers' knowledge of language form, content, and use. *Developmental Disabilities Bulletin*, 32, 140–154.
- Menninga, A., Van Dijk, M. W. G., Cox, R. A., Steenbeek, H. W., & Van Geert, P. L. C. (2016). *The dance of syntactic complexity: A CRQA analysis on co-adaptation processes of syntactic complexity in real-time teacher-pupil interactions during an intervention in kindergarten science lessons*. Manuscript submitted for publication.
- National Research Council. (2013). *Next generation science standards: By states, for states*. Washington, DC: National Academies Press.
- Neumann, K., Fischer, H., & Kauertz, A. (2010). From PISA to educational standards: The impact of large-scale assessments on science education in Germany. *International Journal of Science and Mathematics Education*, 8, 545–563.
- Oliveira, A. W. (2010). Improving teacher questioning in science inquiry discussions through professional development. *Journal of Research in Science Teaching*, 47, 422–453. doi:10.1002/tea.20345
- Patrick, H., Mantzicopoulos, P., Samarapungavan, A., & French, B. F. (2008). Patterns of young children's motivation for science and teacher-child relationships. *The Journal of Experimental Education*, 76, 121–144. doi:10.3200/JEXE.76.2.121-144
- Peisner-Feinberg, E. S., Burchinal, M. R., Clifford, R. M., Culkin, M. L., Howes, C., Kagan, S. L., et al. (2001). The relation of preschool child-care quality to children's cognitive and social developmental trajectories through second grade. *Child Development*, 72, 1534–1553. doi:10.1111/1467-8624.00364
- Peterson, S. M., & French, L. (2008). Supporting young children's explanations through inquiry science in preschool. *Early Childhood Research Quarterly*, 23, 395–408. doi:10.1016/j.ecresq.2008.01.003
- Randi, J., & Corno, L. (2005). Teaching and learner variation. *Pedagogy: Teaching for learning. Monograph series II: Psychological aspects of education*, 3, 47–69. doi:10.1348/000709905X62110
- Sameroff, A. J., & Mackenzie, M. J. (2003). Research strategies for capturing transactional models of development: The limits of the possible. *Development and Psychopathology*, 15, 613–640. doi:10.1017/S0954579403000312

- Scheele, A. F., Leseman, P. P. M., Mayo, A. Y., & Elbers, E. (2012). Relations of home language and literacy with three-year-old's emergent academic language in narrative and instruction genres. *The Elementary School Journal*, 112, 419–444.
- Schleppegrell, M. J. (2001). Linguistic features of the language of schooling. *Linguistics and Education*, 12, 431–459. doi:10.1016/S0898-5898(01)00073-0
- Schleppegrell, M. J. (2004). *The language of schooling: A functional linguistics perspective*. Mahwah, NJ: Erlbaum.
- Schneider, J. W. (2015). Null hypothesis significance tests. A mix-up of two different theories: The basis for widespread confusion and numerous misinterpretations. *Journal Scientometrics*, 102, 411–432. doi:10.1007/s11192-014-1251-5
- Schwarz, C. V., Gunckel, K. L., Smith, E. L., Covitt, B. A., Bae, M., Enfield, M., et al. (2008). Helping elementary preservice teachers learn to use curriculum materials for effective science teaching. *Science Education*, 92, 345–377. doi:10.1002/sce.20243
- Snow, C. E. (1972). Mothers' speech to children learning language. *Child Development*, 43, 549–565. doi:10.2307/1127555
- Snow, C. E. (1983). Literacy and language: Relationships during the preschool years. *Harvard Educational Review*, 53, 165–189. doi:10.17763/haer.53.2.t6177w39817w2861
- Snow, C. E. (2010). Academic language and the challenge of reading for learning about science. *Science*, 328, 450–452. doi:10.1126/science.1182597
- Snow, C. E. (2014). *Deep comprehension: What does it look like in two- to three-year-olds?* [PowerPoint slides]. Retrieved from http://www.lucasacademie.nl/uimages/CatherineSnow_ECESS2014%20%282%29.pdf
- Snow, C. E., & Ferguson, C. A. (1977). *Talking to children*. Cambridge, UK: Cambridge University Press.
- Snow, C. E., & Uccelli, P. (2009). The challenge of academic language. In D. R. Olson & N. Torrance (Eds.), *The Cambridge handbook of literacy* (pp. 112–133). New York: Cambridge University Press.
- Steenbeek, H., & van Geert, P. (2005). A dynamic systems model of dyadic interaction during play of two children. *European Journal of Developmental Psychology*, 2, 105–145. doi:10.1080/17405620544000020
- Sternberg, R. J., & Horvath, J. A. (1995). A prototype view of expert teaching. *Educational Researcher*, 24, 9–17. doi:10.3102/0013189X024006009
- Sullivan, G. M., & Feinn, R. (2012). Using effect size, or why the P value is not enough. *Journal of Graduate Medical Education*, 4, 279–282. doi:10.4300/JGME-D-12-00156.1
- Todman, J. B., & Dugard, P. (2001). *Single-case and small-n experimental designs: A practical guide to randomization tests*. Mahwah, NJ: Erlbaum.
- Van Dijk, M. W. G., & Van Geert, P. (2011). Exploring patterns of adaptation in child directed speech during the process of early grammaticalization of child language. *Language, Interaction and Acquisition*, 2, 61–81. doi:10.1075/lia.2.1.03dij

- Van Dijk, M., Van Geert, P., Korecky-Kröll, K., Maillochon, I., Laaha, S., Dressler, W. U., et al. (2013). Dynamic adaptation in child-adult language interaction. *Language Learning*, 63, 243–270. doi:10.1111/lang.12002
- Van Geert, P. (1991). A dynamic systems model of cognitive and language growth. *Psychological Review*, 98, 3–53. doi:10.1037/0033-295X.98.1.3
- Van Geert, P., & Steenbeek, H. (2005). The dynamics of scaffolding. *New Ideas in Psychology*, 23, 115–128. doi:10.1016/j.newideapsych.2006.05.003
- Van Geert, P. L. C., Steenbeek, H. W., & Van Dijk, M. W. G. (2011). A dynamic model of expert-novice co-adaptation during language learning and acquisition. In M. Schmid & W. M. Lowie (Eds.), *Modeling bilingualism: From structure to chaos* (pp. 235–266). Amsterdam: John Benjamins.
- Vasilyeva, M., Huttenlocher, J., & Waterfall, H. (2006). Effects of language intervention on syntactic skill levels in preschoolers. *Developmental Psychology*, 42, 164–174. doi:10.1037/0012-1649.42.1.164
- Wasik, B. A., & Bond, M. A. (2001). Beyond the pages of a book: Interactive book reading and language development in preschool classrooms. *Journal of Educational Psychology*, 93, 243–250. doi:10.1037/0022-0663.93.2.243
- Wasik, B. A., Bond, M. A., & Hindman, A. (2006). The effects of a language and literacy intervention on Head Start children and teachers. *Journal of Educational Psychology*, 98, 63–74. doi:10.1037/0022-0663.98.1.63
- Wellington, J., & Osborne, J. (2001). *Language and literacy in science education*. London: McGraw-Hill Education.
- Wetzels, A. F. M., Steenbeek, H. W., & Van Geert, P. L. C. (2016). *Primary science teaching: The effect of a coaching program on the behavior of teachers and their pupils*. Manuscript submitted for publication.
- Wong Fillmore, L., & Snow, C. E. (2002). What teachers need to know about language. In C. Temple Adger, C. E. Snow, & D. Christian (Eds.), *What teachers need to know about language* (pp. 7–47). McHenry, IL: Delta Systems Company and the Center of Applied Linguistics.
- Zucker, T. A., Justice, L. M., Piasta, S. B., & Kaderavek, J. N. (2010). Preschool teachers' literal and inferential questions and children's responses during whole-class shared reading. *Early Childhood Research Quarterly*, 25, 65–83. doi:10.1016/j.ecresq.2009.07.001